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The experimental evidence of the amplified spontaneous emission of Yb^{3+} ions in $LiYbF_4$ crystal

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ABSTRACT

The experimental evidence of the amplified spontaneous emission of Yb^{3+} ions in $LiYbF_4$ crystal, which partially stipulates up-conversion processes in Yb-sensitized phosphors, doped by rare-earth ions are presented for the first time. To do that the spatial distributions and the spectra of Yb^{3+} ions luminescence along the excitation radiation propagation through the sample were studied simultaneously. The laser diode radiation (1 W, λ=932 nm) was used for the luminescence excitation and its surface power density was varied by shifting of the position of the laser beam waist within the sample (similar to Z-scanning).

1. Introduction

The upconversion (UC) luminescence of the rare-earth ions doped crystals is typically caused by a combination of the numerous multiphoton and cooperative processes: a) cross-relaxation, b) excited-state absorption of excitation and/or fluorescence radiation, c) energy transfer and energy migration etc [1–3].

The co-doping of the crystalline materials by Yb^{3+} ions with appropriated optical excitation allows enhancing UC efficiency and even realizes the effective UC pumped lasing [4–8]. Yb^{3+} ions sensitized rare-earth ions doped nanoparticles also demonstrate high effective UC luminescence and it is widely used for many various applications [9–12]. Usually the role of Yb^{3+} ions in the UC processes is considered to be sensitizer only.

To study UC luminescence, the spectral and kinetic luminescence characteristics versus the pump radiation power are traditionally measured at stable focusing of the laser beam on a surface of a sample. In this case, the spatial distribution of the excitation and luminescence power inside the sample is ignored. The recent comprehensive studies demonstrate the necessity of taking into account the spatial distribution of excitation radiation and UC emission inside the sample and assume that there is a hidden amplified spontaneous emission (ASE) within Yb^{3+} ions assemble. The hidden ASE plays a dominant role in the excitation of the up-conversion luminescence of Tm^{3+} ions in Yb^{3+}-doped YF_3 [13,14] and Ho^{3+} ions in $LiYbF_4$ single crystals [15].

Here we present the results of study of spatial distributions and the spectra of Yb^{3+} ions luminescence along the excitation radiation propagation through the sample using Z-scan technique [16,17] and demonstrate the experimental evidence of the amplified spontaneous emission due to $^2F_{5/2}$-$^2F_{7/2}$ transitions of Yb^{3+} ions in $LiYbF_4$ crystal.

2. Material and methods

A $LiYbF_4$ crystal grown using the Bridgman-Stockbarger technique in Kazan Federal University was cut in the form of a parallelepiped with dimensions ~ $3\times4\times10$ mm. The c-axis of the crystal sample was oriented along the shortest side and it was perpendicular to the z-axis of the experimental setup (Fig. 1). The Yb^{3+} ions luminescence was excited by the radiation of a semiconductor laser diode (LD) with a maximal power of 1 W at λ=932 nm. All the experiments were performed at a temperature of 300 K. The luminescence spectra were recorded with StellarNet spectrometer (spectral resolution 0.5 nm). To avoid an overloading of the spectrometer with intensive excitation radiation, the luminescence spectra were taken perpendicularly to the laser beam. The longitudinal cross sections of the luminescence were photographed with a ToupCam VCMOS14000KPA MT9F002 camera, attached to measuring microscope (magnification 25/50). The luminescence of Yb^{3+} ions was separated with an infrared filter (cutoff wavelength $\lambda > 0.95$ μm).

The spatial distributions and the spectra of Yb^{3+} ions luminescence along the excitation radiation propagation through $LiYbF_4$ sample were studied simultaneously using the Z-scan technique. The standard Z-scan technique is based on the registration of intensity of focused laser beam passing through the

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